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ON AN INSTRUMENT FOR THE MEASUREMENT OF ULTRAVIOLET RADIATION EQUIPPED WITH A SPHERICAL ATTACHMENT FOR THE MEASUREMENT OF RADIATION INCIDENT AT A LARGE ANGLE

K. Larche and R. Schulze

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ON AN INSTRUMENT FOR THE MEASUREMENT OF ULTRAVIOLET RADIATION EQUIPPED WITH A SPHERICAL ATTACHMENT FOR THE MEASUREMENT OF RADIATION INCIDENT AT A LARGE ANGLE

By Kurt Larche and Reinhart Schulze, Berlin

(Report by the Study Group for Electrical Illumination)

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1. Tasks to be Performed

When making radiation measurements it is very often required to measure the total radiation over a large angular distribution. The best known example of this kind of a measurement is for instance, the determination of total hemispherical celestial radiation incident on a horizontal plane, one of the basic tasks of bioclimatology. Most recently the same type of radiation measurements have to be made for installation and rooms with artificial radiation, for which there is an increasing demand as ultraviolet radiation rooms and tropical test rooms. In these rooms the radiation is incident on the subject exposed to radiation over a large angular distribution. If it is, therefore, required to make a correct measurement of the quantity of radiation incident per unit area of the object, the radiation sensitive area of the instrument has to have the same sensitivity for all angles of incidents. This is a relatively simple task if it is required to measure the total radiation. The thermoelectric instruments provided for this purpose have radiation sensitive areas which are nearly theoretically "black bodice" and which absorb the incident radiation equally for all angles of incidents. It becomes more difficult if it is desired to make measurements of individual narrow spectro-regions in the visible and even more so in the ultraviolet region. In most cases thermoelectric radiation sensors cannot be used because of their low sensitivity. Measurements in the ultraviolet spectro-region were made by the cadmium-vacuum photocell (with a spherical cathode for all-directional incidents) because of its greater sensitivity and by instruments based on the photochemical reaction of some liquids [1]. Both instruments do not fulfill the requirements for a technical instrument for the daily routine use in the laboratory and because of required quality control during production. In the case of the cadmium cell this is because of its complicated structure and the difficulty with which electrometric measurements can be made, in the case of the instrument using liquids it is because of their bulk and time consuming method of measurement.

2. The UV-Instrument According to Krefft and Roessler

In contrast to the above, the instrument for ultraviolet measurements developed several years ago by Krefft and Roessler is very simple to operate and uses as a radiation sensor a selenium-barrier layer cell [2, 3]. By a combination of suitable glass-and liquid filters a narrow spectro-band in the ultraviolet is separated (350 to 410 mμ, 320 to 355 mμ, 295 to 335 mμ, 270 to 320 mμ, 230 to 310 mμ). In conjunction with the recently commercially available technical light-beam galvanometers, the UV-instrument has all desired characteristics for a technical instrument: simple operation, always ready for operation, immediate readings and sufficient reproducability. It has also proved itself in daily use such as, as an instrument used with the Ulbricht's sphere used in the production control of UV-radiation sources.

This handy instrument can on the other hand, be used as is for measurements in rooms with artificial solar radiation. A very pronounced angular dependency of the sensitivity is caused by the required glass and liquid filters which have a considerable thickness. Figure 1 shows the sensitivity of the UV-instrument for an intermediate UV-spectro-band (270 to 320 mμ) as a function of the angular incidents of the radiation. If the sensitivity is independent of the angle of incidents it would have to follow the cos-law and the measured point on the curve would have to be on a straight line (Lambert's cos-law). As can be seen from the Figure, the deviation from the cos-law is considerable. The problem at hand was now to make the sensitivity of the UV-instrument with its different sets of filters for the individual spectro-regions independent from the angle of incidents. Several such experiments had been made previously using barrier layer cells /_4_/, but the corrections made applied only for the individual case and were not of general use. Because of the

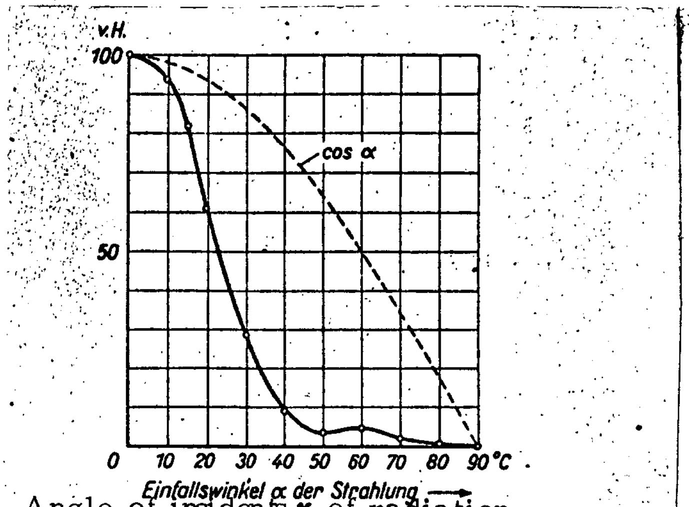

Abb. 1. Relative Empfindlichkeit des UV-Meßgerätes für mittelwellige UV-Strahlung (270 bis 320 mμ) in Abhängigkeit vom Einfallswinkel der Strahlung

Fig. 1. Relative sensitivity of the UV-instrument for medium range UV range (270 to 320 mμ) as a function of the angle of incidents of radiation.

strong vignetting effect of the filters, the only basic solution possible was the use of a type of Ulbricht's sphere. The use of an Ulbricht sphere for this purpose is not new /‾4‾/, but our experiments showed that the sphere has quite definite dimensions in order to make sufficiently accurate corrections.

3. The Spherical Attachment

To start, an Ulbricht sphere of very simple configuration was placed in front of the UV-instrument. The sphere was equipped with equally-sized openings for the radiation entrance and exit and with a radiation shield of somewhat larger size in the center (see Figure 2). The result of the measurement was unsatisfactory (see Figure 3). The deviation from the cos-law was largest in the vicinity of vertical incidents. If the radiation shield and the entrance opening are of equal size, the radiation falls at vertical incidents exclusively on the radiation shield and thus, therefore, does not come through the exit opening before having been reflected at least 2 times (see Figure 2).

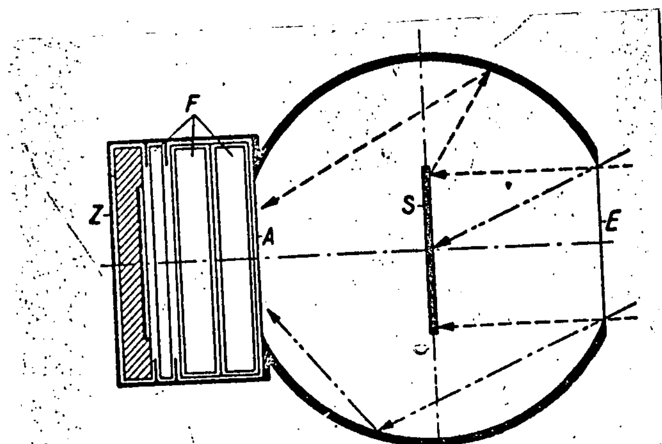

Abb. 2. UV-Meßgerät mit Vorsatzkugel mit gleich großer Eintritts- und Austrittsöffnung. Strahlengang bei senkrechtem und schiefem Einfall
E = Eintrittsöffnung, A = Austrittsöffnung, S = Schatter, F = Filter, Z = Sperrschichtzelle

Fig. 2. UV-instrument with spherical attachment with equal-sized entrance and exit opening. Radiation plotted for vertical and oblique incidents.
E = entrance opening, A = exit opening, S = radiation shield, F = filter, Z = barrier layer cell.

A substantial part of the incident radiation leaves the sphere again through the exit opening. In the case of oblique incidents on the other hand, part of the radiation falls directly on the rear side of the sphere and, therefore, leaves through the exit opening only after a single reflection. For this reason the deviation from the cos-law is in direction of decreasing incidents of radiation (see Figure 3).

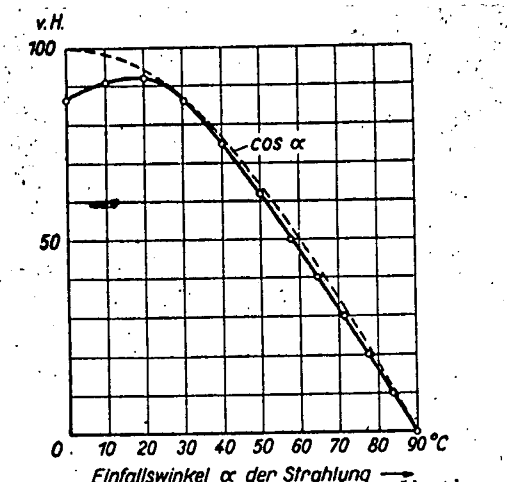

Abb. 3. Relative Empfindlichkeit des UV-Meßgerätes mit Vorsatzkugel nach Abb. 2 in Abhängigkeit vom Einfallswinkel der Strahlung

Fig. 3. Relative sensitivity of the UV-instrument with spherical attachment according to Figure 2 as a function of the angle of incidents of radiation.

After trying several methods to eliminate this fault (for instance, ring shaped radiation shields, double radiation shield, etc.), the relatively simple arrangement described below was constructed. The entrance opening of the sphere is made considerably larger than the exit opening and also larger than the radiation shield, where the radiation shield has to be larger than the exit opening. This makes it possible that now that also for vertical incidents, part of the radiation passes by the radiation screen and falls on the rear surface of the sphere and can leave through the exit opening after only a single reflection.

The radiation shield was made in the shape of a cone in order to decrease the part of the incident radiation which leaves again through the entrance opening after having been reflected from the radiation shield. The efficiency of the arrangement according to Figure 4 is, therefore, twice as good as the one according to Figure 2.

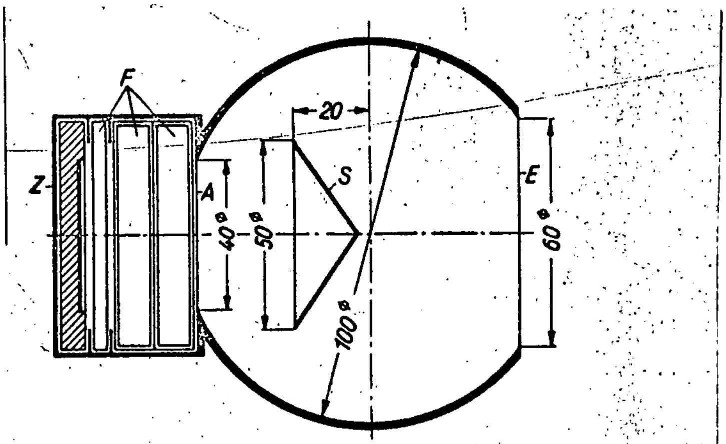

Abb. 4. UV-Meßgerät mit Vorsatzkugel für den Wellenlängenbereich 270 bis 320 mμ

Fig. 4. UV-instrument with spherical attachment for the wave band of 270 to 320 m μ.

A good approximation of the desired angular dependency was achieved by using the dimensions given in Figure 4. The sphere K has an inside diameter of 100 mm and is equipped with two oppositely located circular openings of 40 and 60 mm diameter. The smaller opening has a flanged neck so it can be attached to the housing of the cell. The larger opening has a sharply defined rim. The radiation shield is in the form of a cone-shaped shell of 50 mm diameter and a height of 17 mm. It is placed with its point towards the entrance opening at such a distance from the detector opening that its larger diameter has a distance of 20 mm from the center of the sphere. The inside surface of the sphere is coated with magnesium oxide which also has a high and spectrally independent reflectivity for UV. The coating of magnesium oxide either produced by the known method of burning metallic magnesium or by painting with a paste consisting of magnesium oxide powder and water glass.[1)]

As shown in Figure 4, the filter set for the wave region of 270 to 320 mμ [2] is placed behind the sphere. The liquid filter chambers are made of quartz glass and contain on the entry side a solution of cobalt-nickel sulphate (10 mm), then picric acid (10 mm). The glass filter in front of the barrier layer cell is a UG 5-filter (3mm) made by Schott (Jena).

The spherical attachment was originally developed for this particular filter arrangement which has, because of its overall thickness of 25 mm, the definitely directional sensitivity characteristics as shown in Figure 1. The spherical attachment can also be used for other filter arrangements of the UV-instrument [2, 3], but it has to be observed that the distance between the exit opening of the sphere and the cell surface is not more than 20 mm. In the same manner the described spherical attachment can also be used for other radiation measurement instruments if they are constructed along similar lines as the described instruments.[2)]

4. Angular Dependence of the Sensitivity of the UV-Spherical Attachment

In the case of the instrument described, the effective area for the measurement of radiation flux is the entrance opening of the spherical attachment. The instrument was, therefore, tested for the angular dependence of

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1)Ratio of mixture: 30 g MgO in 200 cm^3 water glass of specific weight 1.08 (according to M. W. Mueller and F. Roessler).

2)For additional filter combinations for the visible and the UV, see [5].

its sensitivity by turning it around an axis which lies in the plane of the entrance opening. The radiation source was placed at a distance of 100 cm. The result of the measurement is shown in Figure 5. The dashed curve corresponds to a strict fulfillment of the required angular dependency. The measured points come close to this curve. The exact magnitude of the deviation for various angles is shown in Figure 6. The deviations of the measured values are plotted against values of per 100 of the theoretical values for the angles of incidents of 0 to 90° for an inclination of the sphere in both directions. The deviation up to an angle of 70° is at the most 2 per 100 and is not systematic. The sensitivity for 90° is zero. The above series of measurements shows only for 80° a deviation of 5 to 6 per 100 which is insignificant because of the low sensitivity at this angle.

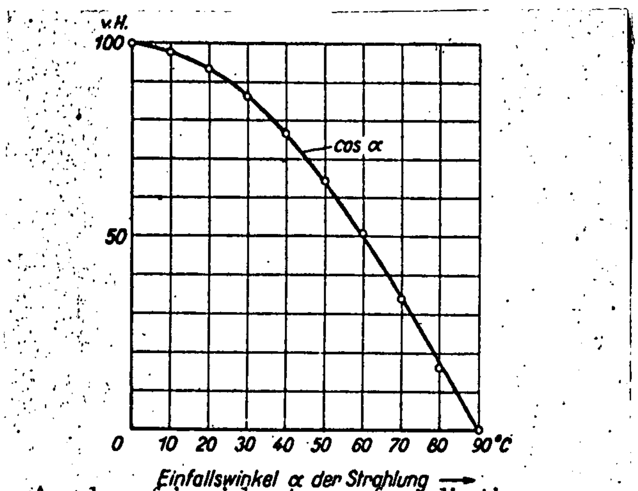

Abb. 5. Relative Empfindlichkeit des UV-Meßgerätes mit Vorsatzkugel nach Abb. 4 in Abhängigkeit vom Einfallswinkel der Strahlung

Fig. 5. Relative sensitivity of the UV-instrument with spherical attachment according to Fig. 4 as a function of angle of incidents of radiation.

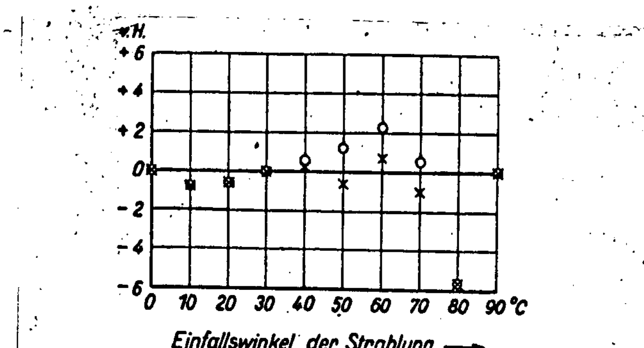

Abb. 6. Abweichung der Meßwerte der Meßreihe nach Abb. 5 vom cos-Gesetz in v.H. des Sollwertes

Fig. 6. Deviation of the measured values according to Fig. 5 from the cos-law in per 100 in theoretical values.

5. Examples of Application.

The sensitivity of the described UV-instrument with spherical attachment is 6 per 100 of the value without the sphere. In order to give an indication for the absolute sensitivity of the instrument it should be mentioned that when using the so-called UV-standard, a radiation standard [6] recently used for UV-measurements, when placed at a distance of 0.5 m will give a deflection of 120 scale divisions of a technical light beam galvanometer (sensitivity 4×10^{-9} A/division). The radiation sensitivity of this arrangement is, therefore, approximately 5×10^{-5} W/division for the wave region of 270 to 320 mμ.

The sensitivity is sufficient to measure the UV-radiation of the sky. The following table gives measurement results obtained in July 1941 and October 1939 around noontime in Berlin on the roof of a factory building with a nearly cloudless sky. It is, therefore, possible during July to obtain a radiation flux density on a plane vertical to the incident soil radiation for a wave length region of 270 to 320 mμ which corresponds to the value obtained from a UV-standard at a distance of 62 cm with interposed WG-6 Schott-filter of 2 mm thickness. By shielding against direct sunlight the component of the diffused celestial radiation of the total UV-radiation for the wave length below 320 mμ was determined to be approximately 60 per 100 in July and 70 to 75 per 100 in October.

Radiation flux densities of equal order of magnitude are present in rooms with artificial solar radiation and apply for radiation instruments used for tropical tests, in which case the angle of incidents of the radiation on the measuring plane is also large. The instrument proved to be quite useful for measurement in such rooms and for such instruments and we shall report on

Numerical Table

Measurement of solar and celestial radiation in the wave band of 270 to 320 mμ with the UV-instrument with spherical attachment

Date	Time	Position of the Instrument	Radiation Flux Density*) Total per 100	Sun per 100	Sky per 100	Radiation Component of Sky of the Radiation of Sun + Sky per 100
10/5/39	12:30	horiz.	38	9	29	76
10/5/39	12:30	⊥ Sun	47	14	33	69
8/7/41	12:00	horiz.	60	25	35	58
8/7/41	12:00	⊥ Sun	65	28	37	57

*) In per 100 of the radiation flux density of the UV-standard at a distance of 50 cm passing through the WG 6-filter (2mm) by Schott (Jena).

Zahlentafel

Messung der Sonnen- und Himmelsstrahlung im Wellenlängenbereich von 270 bis 320 mμ mit dem UV-Meßgerät mit Kugelvorsatz

Datum	Zeit	Stellung des Meßgerätes	Bestrahlungsstärke*) Gesamt v. H.	Sonne v. H.	Himmel v. H.	Anteil der Himmelsstrahlung an der Strahlung Sonne + Himmel v. H.
5. 10. 39	12^{30}	horiz.	38	9	29	76
5. 10. 39	12^{30}	⊥ Sonne	47	14	33	69
8. 7. 41	12^{00}	horiz.	60	25	35	58
8. 7. 41	12^{00}	⊥ Sonne	65	28	37	57

*) In v. H. der Bestrahlungsstärke des UV-Normals in einem Abstande von 50 cm unter Vorschaltung des WG 6-Filters (2 mm) von Schott (Jena).

in the near future.

6. Summary

The UV-instrument is described by Krefft and Roessler and consisting of selenium-barrier layer cells as well as glass and liquid filters becomes suitable for radiation incident at large angles when using a spherical attachment with suitable dimensions. Up to an angle incidents of 70° the sensitivity of the new instrument is within 2 per 100 proportional to the cos of the angle of incidents. The usefulness of the instrument for technical and climatological UV-measurements is shown at the hand of a few examples.

7. Literature

[1] Literatur bei K. Büttner, Physikalische Bioklimatologie. Akademische Verlagsges., Leipzig (1938), 22f.

[2] H. Krefft u. F. Rößler, ZS. f. techn. Phys. 17, Nr. 11 (1936), 479 bis 481.

[3] F. Rößler, ZS. f. techn. Phys. 20, Nr. 10 (1939), 290 bis 293.

[4] Handbuch der Lichttechnik, Verlag J. Springer, Kap. C6, R. Sewig: Objektive Photometrie, S. 345; Kap. C2, W. Dziobek: Verfahren der visuellen Photometrie, S. 276.

[5] Handbuch der Lichttechnik, Verlag J. Springer, Kap. B9, H. Ewest u. K. Larché: Entladungslampen für Sonderzwecke, S. 197.

[6] H. Krefft, F. Rößler u. A. Rüttenauer, ZS. f. techn. Phys. 18, Nr. 1 (1937), 20-25; F. Rößler, Ann. d. Phys. (5) 34, Nr. 1 (1939), 1-22.

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